

Chapter 2

Supporting Tools of Solar-Terrestrial Science

2.1 Introduction

Solar-terrestrial science is pursued by individuals and teams of workers situated in academia, research institutes, industry, and government laboratories. Progress in the field is made in various ways, but publication of results in scientific journals is the principal means of assuring that the knowledge gained from research is available to the public, now and in the future. In general, much of the research in the field is made via careful evaluation of data viewed in the context of fundamental physical principles as set forth in theoretical and analytical models, and computer simulations of physical processes. In addition, there is accumulation of knowledge expressed in the development of empirical or phenomenological models.

Experience gained over the past three decades of solar-terrestrial research indicates that advances in the field require a diversity of resources and that the health of the entire discipline depends upon a balance among these. To maintain the health of the discipline, NASA and other federal funding agencies concerned with solar-terrestrial research must work together to insure that the resources described in the following paragraphs are available in reasonable measure to support solar-terrestrial research endeavors.

2.2 Facilities and Tools

2.2.1 Ground-Based Facilities

Ground-based facilities are important for the progress of solar-terrestrial research. These include various types of optical and near-infrared observatories, atmospheric and ionospheric radars, radio transmitters, and other systems which provide for the monitoring of the upper atmosphere, ionosphere, magnetosphere, and the sun.

2.2.2 Balloons and Rockets

A continuous balloon and rocket program is essential to support innovative and small scale research activities and instrument development. The concept that the shuttle would be able to replace the NASA rocket program has proven to be false. It is clear that both rockets and balloons are essential to support the needs of the constitutive fields of solar-terrestrial science, in the next 20 years.

2.2.3 Spacecraft

Measurements in space lie at the heart of progress in space science. These make possible advances in knowledge through interpretation of models of the different processes underlying solar-terrestrial phenomena. The traditional platforms for accomplishing solar-terrestrial research have been free-flying satellites. New opportunities and difficulties have come with the space shuttle, and there are prospects for even more capable platforms to be flown in connection with the US/International space station. There is also an increasing need for in-situ active experiments.

During the workshop, panel members were asked to evaluate their science goals in terms of the following possible space vehicles:

- Small satellites
- Explorer class satellites
- Moderate class satellites
- Large, facility class satellites
- Space shuttle (up to 9 days in space)
- Extended duration space shuttle (up to 16 days in space)
- Serviceable platforms (e.g., the polar platform)
- Astronaut-tended facilities (e.g., the industrial space facility)

- Permanently occupied orbiting facilities (e.g., the Freedom Space Station)
- Lunar facilities, including occupied and automatic/robotic bases or sites
- Tethered platforms, including satellites of appropriate size.

2.3 Information Networks

The rapid growth of digital communication networks has expanded the appetite of the solar-terrestrial sciences community for frequent and rapid access to remote colleagues, data sets, computers, and other products of modern technology located at widely separated locations. There is no facet of solar-terrestrial research which has not benefited from the capabilities provided by NASA's Space Physics Analysis Network. Growth in capabilities of this and future networks is an essential ingredient of growth in productivity and capability needed to manipulate and distribute the large data sets which will come from the space observations of the next decade.

2.4 Computational Resources

The explosion of capabilities of small, medium, and large computers has revolutionized the methods of space science. The parallel growth in capabilities for information display has given even small research groups tools which formerly could be found only at major research laboratories. The ability to develop comprehensive computer models, to scan large data bases, and to view the results with multidimensional clarity has given impetus to greater progress in the field. In order for solar-terrestrial research to keep abreast of these developments, acquisition of these tools in a timely manner must be regarded as a fundamental aspect of the research program. The federal government must be convinced of the need to possess tools capable of meeting the challenges of the next decade's theories and high data volume scientific instruments.

2.5 Theory

Theory of fundamental processes is an essential part of solar-terrestrial research. The

complex interactions of plasmas and magnetic fields, the passage of radiation through atmospheric gases, the interactions of VLF waves with trapped radiation belt particles, solar flares, and the transfer of energy through the geospace system are examples of the physical processes which must be understood. Theoretical studies of complex phenomena play an important role in the progress of the discipline and their support is essential to the well-being of the field. The NASA Solar-Terrestrial Theory Program has been a pathfinder in terms of scientific endeavor, and continued expansion of this type of work is an essential ingredient of the future.

2.6 Models of Solar-Terrestrial Processes

Theoretical models have a special role in solar-terrestrial science. Complete, comprehensive measurements of the physical state of the sun and terrestrial systems are impossible to obtain. Thus, the goal of space experiments and observations has been to obtain key information which could be used to shed light upon the underlying physical processes which can be incorporated into computer models and simulations. In the next decade, there will be a need to provide better general access to realistic computer-based models than has been the case in the past. Examples are the first principle models of high latitude plasma convection, ray tracing programs for a realistic model of plasma in geospace, time-dependent models of magnetospheric convection, three-dimensional graphical models of the magnetosphere, and the evolution of solar plasma motions, magnetic field and coronal radiation during the course of a solar flare. In the past, such models have been the intellectual property of a few individuals who have shepherded their development. In the future, there could be substantial benefit to providing access to a wider community of research scientists.

2.7 Data Bases and Archives

Access to the results of previous observations and experiments in space is an essential ingredient of solar-terrestrial research. The data

archives of the past are certain to become the fonts of new understanding about the sun and Earth in the next decade, if sufficient resources are provided to permit them to yield their treasures. The next decade will see increasing emphasis upon integrating old data with new theories, and it may be possible to confirm new concepts or relationships from space missions of the past. But, this idea suffers from the fact that it is easier to generate interest in pursuing new missions than it is to propose exploiting fully data from the past. The contributions from the past must be recognized for their potential to advancing knowledge of the solar-terrestrial system. NASA has the responsibility to work closely with representatives of solar-terrestrial science to reach the proper state of balance for the next decade.

2.8 Research Students

The thoughts and knowledge of the past are translated into the actions of the future through the training of students at colleges and universities. The Challenger accident and the consequent reduction in space flight experiment opportunities has meant that students who would otherwise have been attracted to the field have made other choices for their research careers. Another factor affecting the field has been the increasing time to consummate experimental programs. This has affected both students and young faculty who view their careers in terms of opportunities available with several years of effort. The steady flow of adequately trained, young scientists into solar-terrestrial research is essential to the health of the discipline and NASA is obligated to take this factor into account in planning for the future.

